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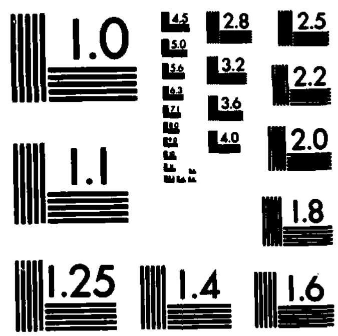

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NEW METHODS FOR STRATEGIC ANALYSIS:
AUTOMATING THE WARGAME

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ACKNOWLEDGMENTS

The development of automated wargaming, as described here, was accomplished by a team of more than three dozen Rand researchers, consultants and supporting staff. Although it is difficult in a development effort as large and complex as this to untangle individual effort from that of the group, there are those for whom special recognition is warranted. Many of our methodological concepts had their origins in the writings of William Jones. The designers of the systems and procedures included Arthur Bullock, James Dewar, Phillip Gardner, James Gillogly, Jerry Koory, Michael Mihalka, and Ronald Shell. Development and implementation involved Roberta Allen, Daniel Gorlin, Marcia Hunt, Thomas McNaugher, Larry Painter, Tracy Rumford, William Schwabe, David Stein, Mitch Tuller and Cindy Williams. Assisting in the demonstration of the system were Herbert Hoover, Donald Jensen, Kevin Lewis, Bruce Powers, Sherry Sims, and James Winnefeld.

INTRODUCTION

This article presents a conceptual overview of a new approach to political-military wargaming which was sought by the Defense Department to improve upon the conventional methods of analyzing strategic forces. Developed at The Rand Corporation during a nine-month demonstration phase, the approach automates all features of political-military gaming from the force calculations to the decision-making participants in the traditional wargame. Machine-controlled players were developed so that the reasons for their actions could be made explicit and reproducible and thereby subjected to debate and systematic analysis.

The ingredients in Rand's approach, computer models and wargames, are not new. How they were combined is. The point of departure for this new approach was the traditional political-military game, but in the process of replacing the players and referees with computer models, the traditional structure was modified, resulting in the introduction of new players and a completely new framework for the analysis of conflict and military forces.

What follows outlines the motivations that led to this approach, the technical challenges it posed, the process of developing and demonstrating the approach, and where it may lead the strategic community in the future. It is based entirely on the experiences accrued during the demonstration phase of the project which concluded in January 1981. The project is now in its second phase.

BACKGROUND

In 1979, at the instigation of the Director for Net Assessment, the Department of Defense solicited proposals for development of improved methodological frameworks to analyze strategic forces. The ultimate objective was to develop a methodology that could be transferred to the government for use by a variety of agencies with diverse interests and purposes. The consortium of potential users included those concerned with net assessment of military forces, program analysis, and operational planning, each requiring different capabilities from the methodology. For example, some might want to use the methodology to explore the effects of various scenarios or adversary perceptions on different measures of the strategic balance, while others might want to examine the effects of different operational plans or force characteristics on war outcomes. Thus, the requested improvements were aimed at a broad enrichment of the analysis of conflicts with respect to a variety of scenarios and their evolutions, adversarial and allied perceptions of political behavior, and the range of military forces that might play in a given conflict.

The motivation for developing improved methods for the analysis of strategic forces can be found in the familiar complaints about much of military analysis.

- It is often limited to the direct effects of engaged forces, without consideration of the interrelated effects of other deployed forces or supporting elements that might be applied to or bear indirectly upon the conflict.

- It is generally limited to canonical scenarios, isolated situations that represent thin slices in time, with little regard for antecedent causes or long-term consequences that may influence the conduct of the conflict.
- It frequently presumes symmetrical perspectives for adversary (and allied) objectives, force employment plans, doctrine, and tactics.

Many of these criticisms might be attributable to limitations inherent in the models used for the analysis of military forces in conflicts (1). But limitations aside, the advantages of current analytic models of strategic conflict are considerable. Assumptions are usually explicit or explicable, particularly in the simpler models. Causes and effects—relationships—are either defined or can be determined. Results can usually be independently reproduced and verified. These characteristics have helped to make computer models the principal analytical tool for the description, evaluation, and communication of strategic force exchange outcomes.

However, such explicit models have been found less and less comforting as the strategic balance between the Soviet Union and United States has shifted. The simple calculations of force exchange outcomes no longer show large margins for error, and some have taken this as a call to sharpen our pencils or our calculus. Critics of strategic force models bemoan the use of a few simple, static measures of force effectiveness and the consequent limited application to a narrow range of military forces having common exchange parameters. And the presumption of a few rather shallow and highly stylized scenarios, focused almost

exclusively on force exchanges, omits much of the complexity of war and the realities of adversary and alliance perceptions or motives.

Political-military gaming has been proposed as an alternative or supplement to computer models of strategic conflict. The distinction between games and models, as the terms are used here, is the use of people as players, who are free to assess and react to hypothetical situations posed to them within the rules and context of the game. Wargaming takes many forms, from bookshelf-chessboard games, to sandtable and field exercises, to formal political-military games involving national-level decisionmakers in hypothetical crisis situations. The form of interest in our endeavor was the political-military game in which the adversary teams, typically RED and BLUE representing the Soviet Union and the United States, decide upon moves or courses of action which may involve both political and military initiatives. Their decisions are mediated by a control team which supplies the adversary teams with any necessary information, interprets their moves, and synthesizes the next hypothetical situation for them to confront.

Political-military gaming of strategic conflict can overcome most of the limitations described above for analytic models, but at the price of losing most of the advantages. Political-military gaming can introduce a rich menu of forces, measures of effectiveness, scenarios, and perceptions but only by relinquishing almost all control over the underlying assumptions, relationships, and reproducibility of the results to the individual judgments and caprices of the players. While the experience for the players may be excellent training, it is extremely difficult

to extrapolate and apply the results directly to the rigorous assessment of policy, program, or operational choices.

In effect, the current analytic models and traditional political-military games represent opposite extremes of a spectrum of advantages and limitations. The desired improvements in strategic methodology demanded a solution that was more than a simple compromise between those two extremes: It called for the best of both--the richness and flexibility associated with gaming, and the reproducibility and transparency obtainable with analytical models. The problem posed, then, was how to introduce the desired enrichment without making the analytic results unsuitable for policymaking because of their complexity, or lack of credibility, generality, and reproducibility.[1]

CONCEPTUAL APPROACH

The conceptual approach started with the structure of a game but replaced the free-play teams with programmed agents. We assumed that this structure would retain much of the rich contextual complexity of gaming, but by controlling the players through the discipline of explicit programs, much of the reproducibility and traceability afforded by analytic models would also be retained. The concept and its potential feasibility were based on three important assumptions:

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[1] Strategic Analysts have stalked this problem for many years. And even within the Rand Corporation, various proposals had surfaced which attempted to redress the analytical shortcomings described above. Of particular interest to the current endeavor is the notion of system synthesis" propounded by Edward Paxson in Cost Considerations in Systems Analysis by Gene Fisher, The Rand Corporation, R-490-ASD, December 1970, pp. 283-301.

- Computer and knowledge engineering technologies now make it possible to consider programming every player, at least for some modest range of play;
- Programming the behavior of players in a game should assist in making the results of games more transparent and reproducible (i.e., more amenable to subsequent analysis);
- The decision to direct or automate selectively any particular combination of players would permit flexible gaming arrangements suitable for a wide variety of users and analytical purposes.

Conceptually, the notion of automating game play, though provocative, was neither unique or new. Computerized games are widely available, and automated players are now acknowledged as competent for games like chess and backgammon (2). For some time, computers have been used to support political-military games, especially for the planning and analysis of military operations. As experience with computer-supported gaming built up, some of those involved in designing and directing games began to speculate on the operational or behavioral codes necessary to program the adversary teams. At the same time, researchers at Rand and elsewhere had theorized about the operational codes required to explain historic Soviet decisionmaking in crisis and conflict situations as a means of exploring anticipated Soviet actions or reactions (3). Thus, sufficient interest and experimental data had accumulated through years of gaming and speculating about political-military decisionmaking to encourage prospects for designing explicit, machine-dictated modeling of political and military decisionmaking in crisis situations.

But the interest in programming the adversary teams was not motivated solely by a desire to codify behavior. It sprang in equal measure from some of the perceived shortcomings of free-play political-military gaming. In such games, it is often impossible to relate expert information to game outcomes. By making the behavior of teams explicit, we would have the opportunity to trace the relationship between inputs and outcomes.

Furthermore, prior experience with political-military gaming has revealed that there are some actions that teams will just not initiate. For example, free-play teams exhibit extreme reluctance (amounting to refusal) to initiate nuclear conflict. While heartening, that reticence does not lend itself to exploration of the circumstances and problems that may attend the transition to (or away from) nuclear conflict. If gaming (as opposed to invoking) the initiation of nuclear conflict holds any analytical value, it might only be possible with a programmed agent.

The task of programming the behavior of a control team posed a particularly severe challenge. In the traditional political-military game, the control team provides several different and demanding functions:

- o The source of political and military information typically provided to decisionmaking bodies by their staffs;
- o The interpreter and arbiter of worldwide political and military actions instigated by the adversary teams;
- o The initiator of worldwide political and military events to stimulate the adversary teams and advance the purposes of the game;
- o The coordinator for all game communications; and
- o The keeper [illegible] the game records and clock.

The concept here was to split the control functions up into three separate "agents" as shown in Figure 1. The Force Operations Agent (FORCE) is responsible for all information, planning, and execution of military operations, worldwide, for the adversaries. The Scenario Development Agent (SCENARIO) is responsible for all political information and actions required to portray the worldwide political situation to the adversaries. The Systems Monitor (MONITOR), in the central position of this new game structure, retains the traditional control team functions of coordinating the game communications and keeping the game records and clock.

This structure is unique in two ways. First, it breaks up the complex functions of the traditional control team into tasks that appear to be programmable or governable by explicit rules. Secondly, by breaking up the control functions, two additional, independent agents of a stature comparable to the adversary agents were created. This latter point is particularly significant because of the flexibility it implies. In essence, a four-sided game board was created where one could selectively automate any or all of the agents:

- By actively directing (free-playing) the BLUE agent, with all the other agents in their automated or programmed mode, it should be possible to explore--in systematic, transparent, and reproducible ways--options for the use of U.S. strategic forces;
- By playing FORCE, with all the other agents programmed, it should be possible to test different force structures or

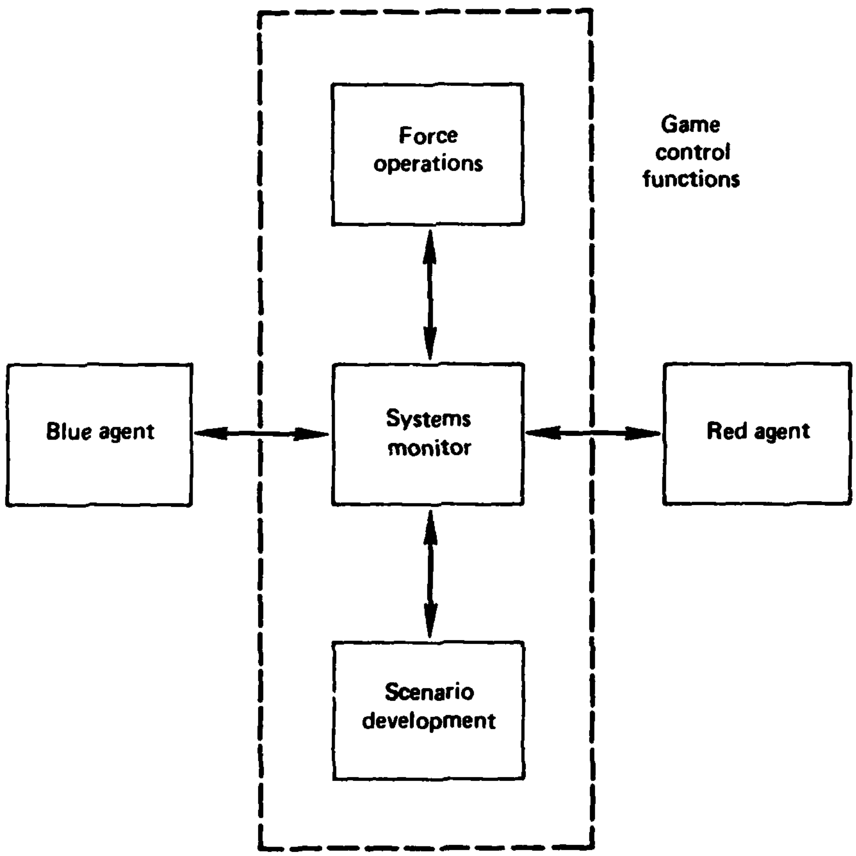

Fig. 1--Game Structure Proposed for Programmed Agents

characteristics under controlled conditions for force-use plans and adversary behavior;

- By playing RED, it should be possible to test the robustness of U.S. forces and plans against a variety of Soviet perceptions and initiatives; and
- By playing SCENARIO, it should be possible to explore the importance of various political and military actions that might be undertaken by third parties to a strategic conflict between the Soviet Union and the United States.

If used in this way, the application and capabilities of the methodology are much closer to traditional analytical models than they are to gaming. While the structure and much of the nomenclature associated with this methodology have their origins in gaming, the interchangeable combination of people and computer programs in teams or agents represents a new and flexible analytical framework. At one extreme, a single analyst might exercise the methodology by manipulating the programmed agents to explore a particular issue under explicit contextual assumptions about such variables as adversary and alliance behavior, or about force capabilities. At the other extreme, several teams of people--including planners and decisionmakers--might direct the agents simultaneously in a free-play exercise that would approach the character of the traditional political-military game.

FEASIBILITY ISSUES

To many, this concept appeared to be very ambitious and risky. To others, the concept seemed so obvious that they were surprised it had not already been done. Obviously, there were different perceptions of what was required to bring the concept to life and of the state of the art available to support its development. While we were reasonably sure that we could program an adversary agent, we were less sure that it could be programmed to the level of detail or degree of sophistication that would make it an interesting player in a political-military game. We were even less certain that we could program some of the agents involved in the game control functions, particularly the worldwide political environment represented by SCENARIO. Finally, we appreciated the potential difficulties in hooking up several game-playing automatons so that they could "talk" to each other in a language that both they and we could understand.

Thus, the immediate concerns were less with the attractiveness of the concept, and more with its technical (or operational) feasibility. It represented a major innovation in gaming that might ultimately tax the state of the art in applied computer and knowledge engineering technologies. Given the acknowledged risks, Rand was asked to demonstrate the salient features of the approach in a first-year contractual effort.

To demonstrate the fundamental principles underlying the conceptual approach, we elected to prove the feasibility of programming an adversary agent by concentrating first-year development efforts on the RED agent. If we were successful in automating RED, we could argue by analogy that we could also program the BLUE agent. With that reasoning, we

took a very conservative approach to programming RED (one that had a high probability of success) and made no attempt to program BLUE: we opted to demonstrate the system feasibility with a free-play BLUE team.

In programming FORCE, no totally new models were built. Because the project was aimed at developing an improved conceptual framework, force modeling, in and of itself, was not where new ground was to be broken. Indeed, force operations is the area where most of the experience with models for strategic analysis originates. Instead, existing models were modified and then integrated in a time-based program which kept track of the pace of force operations events and showed their interactions. The objective in this phase was to achieve maximum flexibility and high-speed computer operations, which necessitated use of highly aggregated force exchange models.

For SCENARIO, a high-risk approach relying on advanced programming techniques was used. The risk was justified by the confidence expressed in the approach chosen to program RED. If the gamble paid off, two different approaches to agent programming could be demonstrated. And if we lost the gamble, a functioning RED automaton would be in place and manual controls (written procedures) could be used to simulate the automation of SCENARIO. We won on the gamble.

For MONITOR, most of the effort was devoted to developing a game language which all of the agents, whether programmed or manually controlled, could understand and generate with automated procedures. Programs for capturing the game records and manual procedures for advancing the game clock were also developed.

AGENT DESCRIPTIONS

To demonstrate the technical feasibility of Rand's concept for automated wargaming, each of the agents was developed to some primitive level of operational capability. The capabilities achieved for each agent by January 1981 are outlined below:

RED Agent (4)

The role of the RED agent is to provide an automated Soviet assessment and response to the conflict situation at hand. The centerpiece of this agent is a "control" program that provides conditional instructions for both political and military actions based upon an interpretation of a categorically defined conflict situation. The conflict situation is inserted into the program in terms of some fifteen parameters or dimensions, such as the parties involved in the conflict, its location, the rules of engagement being observed by the parties to the conflict, the current strategic balance, and projected conflict outcomes. The RED agent control program assigns each parameter a weight which corresponds to the assumed value of that factor in Soviet decisionmaking. The program then uses the weighted factors to locate in its data base an action appropriate to the situation.

The RED agent was not designed to provide the "definitive" prediction of Soviet behavior. Rather, the RED agent program and its data base serve as discipline for being explicit about various alternative assumptions about, or perceptions of, Soviet behavior in conflict situations. Therefore, several data bases were built, each initially loaded with action instructions for about 400 situations. The data bases were

designed to accommodate future development or expansion through analytical experience. Additional action instructions can be loaded whenever the existing data base appears inadequate; and such additions can be made a permanent and reproducible aspect of Soviet behavior as portrayed by that particular data base. For demonstration purposes, we developed four such data bases or libraries of Soviet behavior which we called "IVANs." For example, a library called "IVAN D" exhibited behavior that was consistent with Soviet military doctrinal writing. The four libraries developed for demonstration were a first cut attempt to cover the assumption space concerning Soviet goals and objectives.

FORCE Operations Agent (5)

FORCE is responsible for tracking force status and employment for all the military actions ordered or contemplated by the other agents. For demonstration purposes, most of these actions were brought under the discipline of computer programs; the rest were performed manually by military analysts and entered into the system as if they were computer generated. FORCE is supported by a modular force management program (called FOMENT) that was originally designed to handle strategic conflict for notional weapons and targets. The program was adapted to handle theater and theater nuclear conflicts. The status of forces, for both theater and strategic conflicts, is provided by computer-driven tables and maps. While force allocations and strike plans can be custom designed by free-playing teams, the automated agents operate with a menu of "canned" plans for the allocation of their forces to targets or fronts.

In an on-going game it is impossible to guarantee, in advance, the time jump required to integrate upcoming adversary actions. The inherent unpredictability of gaming required a time-based program flexible enough enough to accommodate modules of varying levels of detail and different types of force interactions. The force management program used is illustrative of the kind of automated FORCE agent necessary in this kind of structure.

SCENARIO Development Agent (6)

SCENARIO is responsible for setting the international political context within the automated wargame. SCENARIO maintains a model of the political world that is described for the other agents as a listing of nations and their relationships to the conflict at hand. This world model is presently designed to track about 150 nations described in terms of their political and military status vis a vis the conflict at hand. The model is driven by a control program written in a knowledge engineering language, ROSIE (7), recently developed at Rand.

The operator for SCENARIO characterizes the conflict situation in 11 parameters for the control program. The program uses this description of the conflict and automated processing of all incoming diplomatic messages as a basis for invoking any of about 50 rules governing changes in the world model. These rules are written in English-like prose in the ROSIE language, so they are readily available for review and revision. In addition to updating the world model, the control program automatically generates outgoing diplomatic messages and provides any free-playing teams with narrative statements of the world political situation.

While the current capabilities of SCENARIO as a model of world politics is primitive, we are very pleased with the potential it shows for sophisticated and transparent programming of automated agents.

Systems MONITOR

MONITOR is responsible for coordinating communications, keeping the game clock, and documentating the exercise. A game language was developed for this purpose that could be automatically processed by all of the agents and easily understood by the players. This language became the diplomatic medium of the game and was transmitted over an automated message handling system.

For demonstration purposes, we elected not to automate the advancement of the game clock, in the belief that the best procedures would become evident from operational experience with the methodology. Thus, we adopted a manual procedure wherein MONITOR would consult with SCENARIO and FORCE and agree upon the smallest clock advance that could present the adversary agents with interesting decision opportunities.

For record-keeping, we simply collected all of the data produced by the agents and wove them together on a common time base. We made no effort during the demonstration phase to build special programs to trap or analyze particular sets of data.

BLUE Agent

The role of the BLUE agent is to provide an automated U.S. assessment and response to the conflict situation at hand. As discussed earlier,

we elected to substitute a free-play team for BLUE agent, relying on the RED agent as a demonstration of our ability to automate an adversary agent. The BLUE team was supported by an advisor trained in the method and procedures and by several technicians who could provide the necessary interface with the automated procedures.

PROCESSING GAME MOVES

This conceptual structure can accommodate a variety of gaming procedures involving the order of moves and the motions of the game clock. For demonstration purposes, we elected to process moves between the two adversaries, RED and BLUE, in a ping-pong mode as opposed to having them both move at the same time. The adversarial agents evaluated their options and determined their actions in frozen time (time stands still), while FORCE and SCENARIO considered events occurring over an increment in time. Thus, RED and BLUE were always presented with a situation at each move opportunity which reflected the results of the previous adversarial move. This was achieved by a strict protocol for processing moves.

Figure 2 shows how moves were processed through each agent during the January 1981 demonstrations. The figure illustrates one half of a complete move (ping-pong) cycle, starting with a move by the free-play BLUE team and ending with the move passing to the RED agent. A similar figure could be drawn starting with a move by the RED agent.

The BLUE team, facing a conflict situation which requires a move decision, begins deliberation with the game clock frozen. BLUE has access to the force status and force employment data kept by FORCE, as

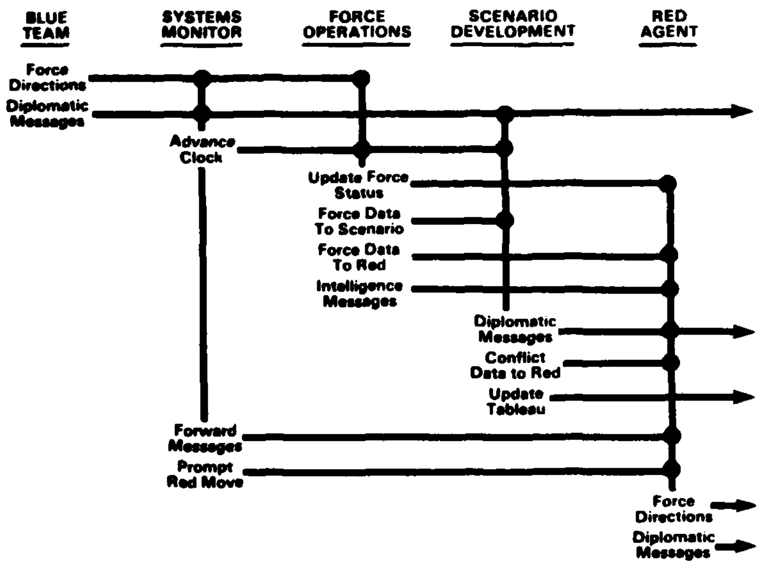

Fig. 2--Move Processing

well as the status of the political world kept by SCENARIO. Based upon this information and consideration of U.S. goals and objectives, BLUE prepares its move or response. A BLUE move might typically consist of requests to FORCE to implement military actions, messages to RED, and messages to SCENARIO as the proxy for the rest of the world.

At that juncture, MONITOR decides the game clock advance (in consultation with FORCE and SCENARIO). Once the clock is advanced, FORCE updates the status of BLUE forces, informs SCENARIO of the force activities undertaken by relevant parties, and passes onto RED any appropriate intelligence information on BLUE force activities. Then SCENARIO processes any messages from BLUE, updates the world political model, generates messages for RED and BLUE from the rest of world, and advises FORCE on political changes which affect military operations.

RED then has the information needed to generate its move. Data from FORCE and SCENARIO and any messages from SCENARIO and BLUE to RED are available as inputs to the RED control program. The resulting move developed by the control program is comparable in structure to the BLUE team move, but because the RED agent is automated, its move is currently much more stylized and limited in content. The RED move is processed back through the other agents in a similar fashion to that just described for the BLUE team move.

The complete move cycle currently requires about 30 minutes, depending upon the complexity of the force operations requested by the free-play BLUE team. These times could be considerably reduced if all agents were automated and put on a single computer.

SOME PRELIMINARY OBSERVATIONS

Very little time was available to experiment with this structure prior to demonstrating it in January 1981. Because the project was working to a very tight deadline, and the objective was to demonstrate technical feasibility, most of the effort was focused on developing and integrating the basic components.

But even the month or so we had to prepare it for a demonstration to the sponsors has given us some glimmers of its unique and potentially powerful personality. What follows are some observations based upon our limited experience thus far with the development and operation of automated wargames.

First, we have been impressed by the discipline that automated wargaming enforces upon those who would develop or play such games. Designing automatons (or agent control programs) forces one to be explicit about so much in military analysis that is traditionally left implicit. We have created a structure that makes us confront, and then traps us in, our assumptions. To program an adversarial agent, one must be very explicit about what makes it decide for or against going to war or escalating a conflict; it is simply not enough to say there is a war. And the kinds of assumptions we are now forced to confront, however awkwardly in our first head-on encounter, seem to be the pivotal ones, the ones that have the potential of driving the answers.

For example, analysts studying conflict typically ascribe various motivations to the superpowers to explain hypothetical (or historical) escalatory actions. To pick a simple example, the Soviets might be seen as entering conflict only if they determine some gain would accrue from

their action. The gain could be monetary, territorial, hegemonic, etc. This structure requires the analyst to be explicit about the gain criteria (it must be loaded into the RED data base in this example), and provides the means to play it out thereby testing the cause and effect relationship of that particular assumption.

Second, automated wargaming appears to provide a different analytical capability from either games, from which it derives its structure, or computer models, from which it draws its discipline. With models, we are accustomed to specifying the scenario as an input. With traditional games, the scenario is something that is actively manipulated for game purposes through the actions of the adversary and control teams. With fully automated wargaming, the programs interact to create a scenario; the scenario becomes an output rather than an input or control. We have relinquished the scenario, as in the real world, to initial conditions and the reactive behavior of the parties involved.

We observed the significance of this point while trying to develop the baseline game used as the point of departure for the system demonstration. We were asked to produce a scenario that followed a particular escalatory path. But we had built a machine that developed its own scenario from the ingredients fed into it, not a machine that followed a prescribed path. The result was frustration. Repeatedly, our automated wargames would fail to escalate or would skip a certain escalation level. Much "fiddling" with the BLUE moves and one override of the SCENARIO control program were necessary before we finally arrived at kind of scenario required by the client to demonstrate the technical feasibility of this system.

Upon reflection, this characteristic may be the most telling. This structure will not create a scenario inconsistent with the assumptions built into the agents. If, then, we start with a situation and the programs spin out a scenario that differs from our expectations, we are motivated to examine our assumptions and expectations.

Third, while our primitive automated agents are not presently programmed to be very sophisticated, we have been impressed with the complexity of play that evolves from the interactions of several simple automatons. Even those who have written control programs for an automated agent have difficulty in predicting its behavior because of the impinging actions of other agents and the conditional and contingent nature of the programmed behavior.

This complexity of interactions between simple automated agents became evident as we tried to integrate the components of our wargaming structure. While we had earlier been concerned about the feasibility of developing individual control programs for the automated agents, we soon learned that developing the agents as separate components was much simpler than integrating them into a working system, much like the experience of those who have tried to integrate electronic black-boxes into navigational or fire-control systems. Consequently we spent more of our effort in working through integration problems between agents than we did in their separate developments.

The concepts we have proposed for automated wargaming appear to offer a unique and useful framework for analyzing strategic force operations. And even at this rudimentary stage of development of automated wargaming, some of us have found that the horizons of our own strategic

thinking are expanding very rapidly. For we see the means, the discipline, and the language in this structure to probe some very fundamental questions about why we have strategic forces and what differences they make under what kinds of circumstances.

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